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Ichthyofaunal list of the continental slope of the southern Gulf of Mexico

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Abstract

Four oceanographic cruises were carried out between April 2011 and May 2013 on the continental slope of the southern Gulf of Mexico (GoM) in a depth range of 290 to 1200 m on board the R/V JUSTO SIERRA. A total of 91 trawls covered a total swept area of 170.49 hectares. We recorded 177 fish species belonging to 80 families. Fifteen species extended their distribution into the south of the gulf and 37 increased their depth ranges. Five species could have commercial importance: *Aphanopus carbo* Lowe, 1839; *Hydrolagus mirabilis* (Collett, 1904); *Helicolenus dactylopterus* (Delaroche, 1809); *Lophius gastrophysus* Miranda Ribeiro, 1915, and *Merluccius albidus* (Mitchill, 1818). The most abundant species were *Polymixia lowei* Günther, 1859; *Parasudis truculenta* (Goode & Bean, 1896); *M. albidus*, *Chlorophthalmus agassizi* Bonaparte, 1840; *Dibranchus atlanticus* Peters, 1876; *Nezumia aequalis* (Günther, 1878); *Yarrella blackfordi* Goode & Bean, 1896; and *Laemonema barbatulum* Goode & Bean, 1883. High values of fish species richness, diversity, and evenness were registered throughout the study area. A high percentage of the fish species (97%) collected during this project are distributed in the entire GoM. Most of the species showed a wide depth distribution; however, a vertical zonation of species can be observed.

Keywords

Deep water, fishes, new records, species richness

Introduction

The Gulf of Mexico (GoM) is one of the most productive and economically important ecosystems in the world (Cato 2009, Tunnell 2009), and its large biodiversity makes it one of the most diverse seawater bodies (Felder et al. 2009). Due to its ecological and economic importance, ichthyofauna studies initially focused on commercial species. Research on fish biodiversity in the GoM, which began in 1850 (Darnell and Defenbaugh 1990), became more systematic and extensive since 1950. A total of 1541 species has been reported in the GoM in the different types of habitats that exist in this large ecosystem (McEachran 2009). Nevertheless, more emphasis has been placed on coastal regions because they are more accessible and economical to survey compared to deeper areas and the open sea.

Few investigations about fish biodiversity have been conducted on the continental slope, and most have focused on different ecological aspects of demersal fish communities in the northern part of the GoM (Pequegnat et al. 1990, Powell et al. 2003). More than 126 mesopelagic fish species were found in this region by Ross et al. (2010), who compared the composition of mesopelagic fishes in three different habitats located at depths between surface and 1000 m. Sulak et al. (2007) documented 53 benthic fishes associated with deep water coral habitats in the north-central gulf. McEachran and Fechhelm (1998) produced one of the most complete ichthyological inventories for the GoM and for the Caribbean Sea's continental slope. In addition, Anderson et al. (1985), Saavedra-Díaz et al. (2004) and Paramo et al. (2015) issued complementary reports of 44 species in this region. Others studies of the deep-water fishes in the Caribbean, but concerning to deep reef fishes have been conducted by Colin (1974); Thresher and Colin (1986); Baldwin and Robertson (2014); Baldwin et al. (2016) and Quattrini et al. (2017).

Since there were not studies of fish communities in the southern deep-water of the GoM, the ichthyological inventory of this ecosystem is not yet completed. The Mexican portion of the GoM deep water has recently become an area of interest because of its oil extraction potential (PEMEX 2016) and its potential fishing resources, where at least three important shrimp species have recently been discovered (Gracia et al. 2010). In a potential scenario of exploitation of both living and non-living resources of deep waters of the GoM, it is crucial to acquire more knowledge about this ecosystem. Biodiversity inventories need to be developed to understand, manage, and conserve these resources.

In this study we present information of the fish biodiversity of the scarce explored continental slope of the southern GoM. Our study is the first one that systematically analyzes the deep-water fish fauna in this region.

Materials and methods

The GoM is in a subtropical region that measures 1600 km from east-to-west and 1300 km from north-to-south. It is influenced by the Caribbean Sea due to the transport of water masses via the Loop Current flowing into the gulf through the Yucatan

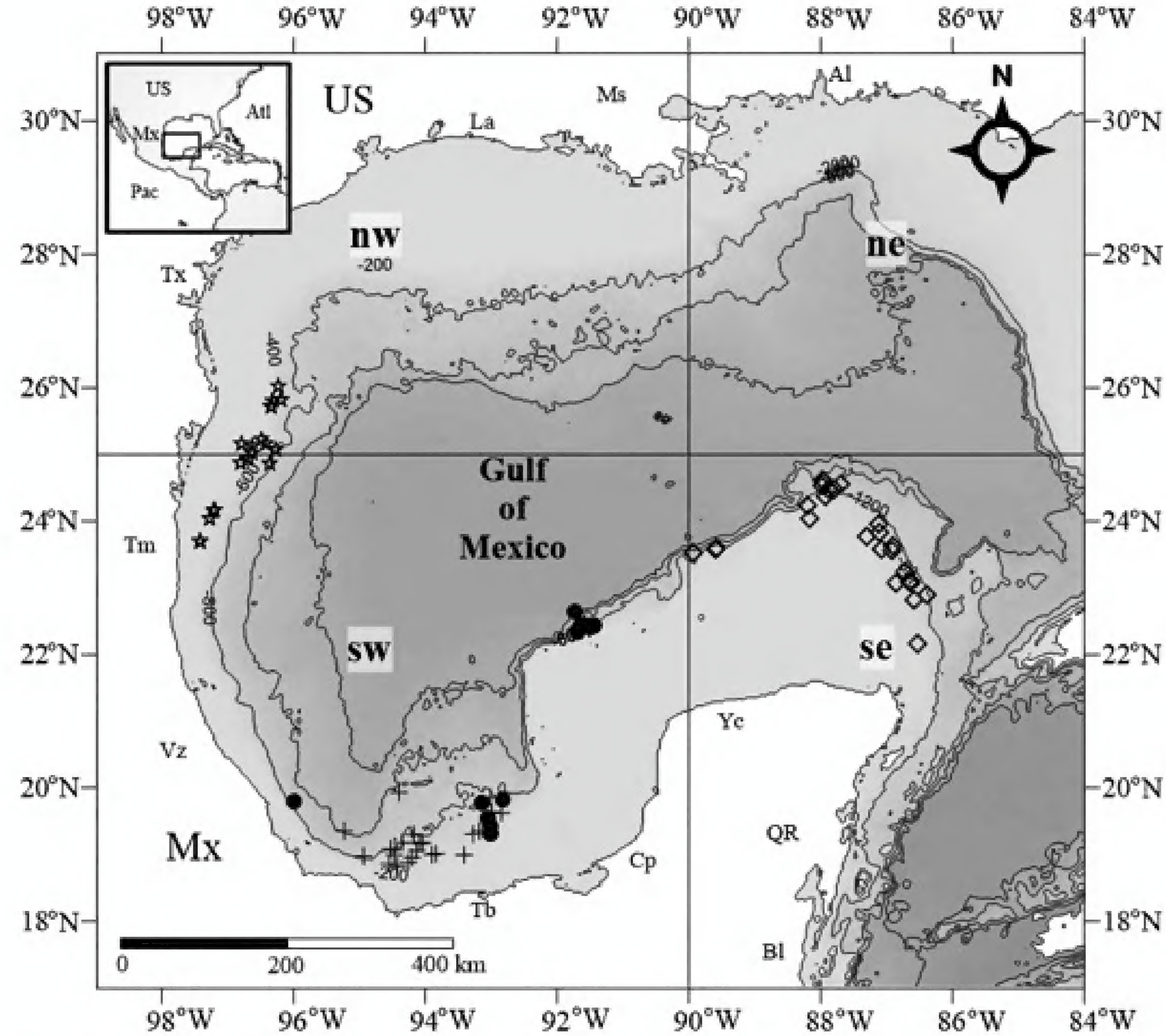

Figure 1. Locations of the oceanographic cruises: COBERPES 2; COBERPES 3; COBERPES 4; and COBERPES 5. Abbreviations: ne: north-east; nw: north-west; se: south-east; sw: south-west; Al: Alabama; Atl: Atlantic; Bl: Belize; Cp: Campeche; La: Louisiana; Ms: Mississippi; Mx: Mexico; Pac: Pacific; QR: Quintana Roo; Tb: Tabasco; Tm: Tamaulipas; Tx: Texas; US: United States; Vz: Veracruz; Yc: Yucatan. Gulf of Mexico division taken from Felder et al. (2009).

Channel and out of the gulf through the Straits of Florida. Winds, especially in winter also impact gulf circulation (Monreal-Gómez et al. 2004) (Fig. 1).

This research forms part of the project "Biodiversity and Potential Fishing Resources in Deep waters of the Gulf of Mexico," through which oceanographic cruises (Benthic communities and potential fishing resources in the Gulf of Mexico deep waters, COBERPES) were conducted on the Mexican continental slope of the GoM on board the R/VJUSTO SIERRA of the Universidad Nacional Autónoma de México.

Four oceanographic cruises were carried out from April 2011 to May 2013: COBERPES 2 and COBERPES 3 on the Yucatan Slope; COBERPES 4, off the coast of Tamaulipas and COBERPES 5 on the Campeche Bank (Table 1). The benthic megafauna of soft bottom substrates was sampled in a depth range of 290–1200 m, using

Table 1. Geographic location and data on oceanographic cruises.

Cruise	Date	Geographic locations				Number of samples	Area (ha)
COBERPES 2	07–15 Apr 2011	23°02'46"N, 86°26'34"W	23°30'98"N, 89°49'42"W	24°22'60"N, 87°42'98"W	22°53'05"N, 86°15'49"W	28	46.79
COBERPES 3	13–19 Nov 2011	22°25'65"N, 91°26'49"W	19°19'38"N, 93°02'54"W	22°23'93"N, 91°37'41"W	19°33'82"N, 93°01'46"W	20	34.87
COBERPES 4	23–30 Aug 2012	23°30'73"N, 97°12'79"W	25°47'30"N, 96°14'83"W	24°54'93"N, 96°36'91"W	25°45'97"N, 96°13'05"W	20	38.58
COBERPES 5	22–31 May 2013	19°03'92"N, 94°05'53"W	18°45'66"N, 94°22'13"W	19°00'80"N, 93°50'35"W	19°48'22"N, 92°59'11"W	23	50.25

a semi-commercial shrimp trawling net with an 18m mouth, a 4.5cm mesh and a 1.5cm cod-end opening. Since information about sea bottom was lacking, sea bed was previously explored using a Multihaz EM 300 echo sounder and a Topas PS-18 sub-bottom profiler. After finding adequate substrate, 30-minute trawls were performed at an average velocity of 77.16 m/min. The distance of each tow was determined by GPS readings. Fauna samples were sorted by taxonomic groups, weighed, and preserved in 10% formalin on board.

In the laboratory, fishes were identified to species level. The names, authorities, and years of the descriptions were cross-referenced against the Eschmeyer database (2017), as well as the geographic and bathymetric distribution of the species was consulted in different web sites: Ocean Biogeographic Information System (OBIS 2018); Smithsonian National Museum of Natural History; Biodiversity of the Gulf of Mexico Database (Moretzsohn et al. 2017); Texas A & M University Corpus Christi, Harte Research Institute for Gulf of Mexico Studies (2017); FishNet 2 (2013); World Register of Marine Species (WoRMS 2017) and FishBase (Froese and Pauly 2017). Each individual was measured, weighed, preserved in 70% alcohol, and retained in the Reference Collection of the Laboratorio de Ecología Pesquera de Crustáceos del Instituto de Ciencias del Mar y Limnología, UNAM. Number of fish species vs. sampling effort was analyzed to determine sample size using the Clench model (Jiménez-Valverde and Hortal 2003) and the freeware Stimates v8 (Colwell 2006). With the biological data was examined the abundance (individuals/ha), richness (number of species), diversity (Shannon and Wiener 1963), and evenness (Pielou 1977) of the fish communities in different sampling areas. The bathymetric distribution of the species was recorded considering the average depth of each trawl.

Results

Ninety-one trawls covering a 290–1200 m depth range were done in the different regions of the southern GoM during the four oceanographic cruises. The numbers of successful trawls at each depth stratum were 300 m: 17; 400 m: 11; 500 m: 16; 600 m: 8; 700 m:

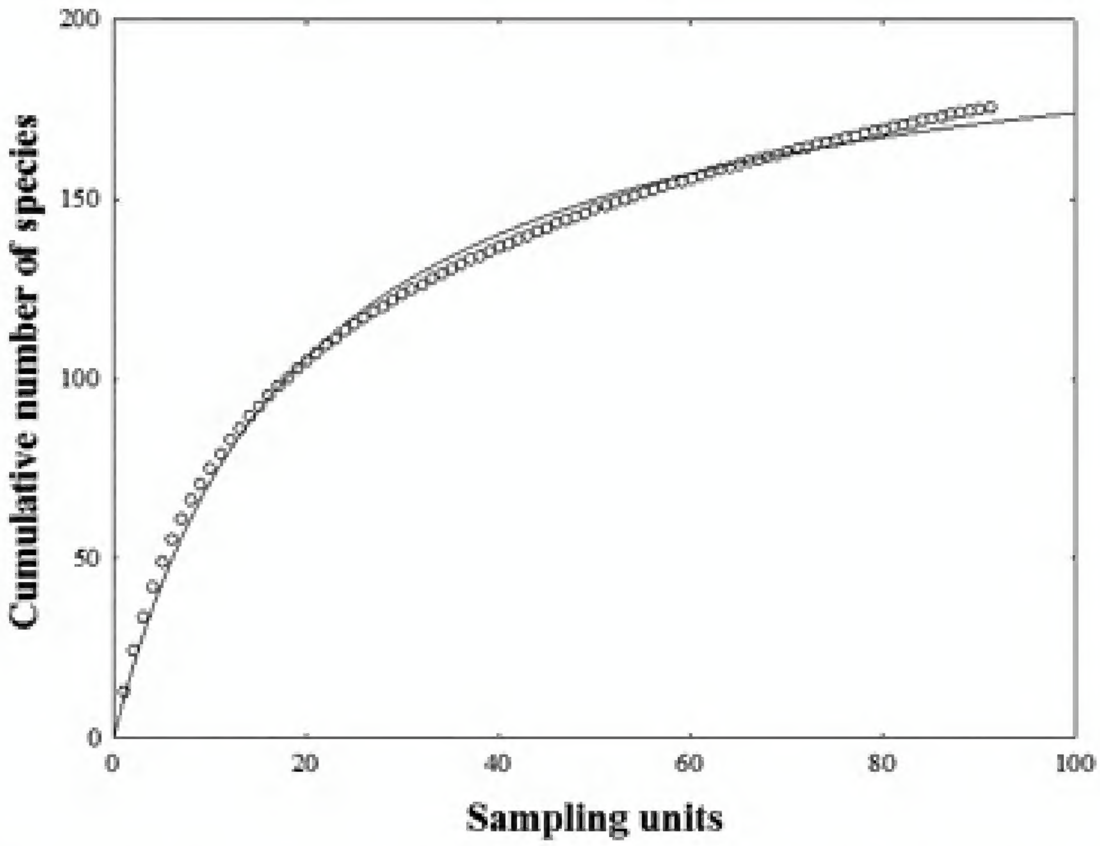

Figure 2. Plot for fish species accumulation for the total sample. Key: circles, random curve; continuous line, fit curve of Clench function (Sn = (10.79*n)/(1+(0.0520*n). Each sample unit consisted of 30 minutes trawl at an average speed of 77.16 m/min (2.5 knots).

11; 800 m: 11; 900 m: 6; and 1000 m: 4, corresponding to 170 hectares total swept area. Seven trawls failed (Table 1). A total of 9781 fishes was caught, belonging to 80 families and 177 species (Table 2). The species accumulation curve related to the number of samples did not reach a clear asymptote; however, data adjusted with a Clench model suggests that 91% species richness of the southern GoM continental slope was recorded (Fig. 2).

The most abundant species were *P. lowei* (1206 individuals), *P. truculenta*, *M. albidus*, *C. agassizi*, *D. atlanticus*, *N. aequalis*, *Y. blackfordi*, and *L. barbatulum*. Among these, *P. lowei* and *C. agassizi* are outstanding, with a relative abundance greater than 10%, and *D. atlanticus*, and *M. albidus* with a relative frequency of more than 50% (Fig. 3).

The lowest richness was found in the Yucatan slope area near the Caribbean Sea (COBERPES 2), with a total of 27 species and a mean of 11.81 ± 5.71 (SD) species per trawl, whereas, the highest one was registered in the Campeche Bay (COBERPES 5) with 39 species (17.26 ± 9.06 species per trawl), however, a high fish species richness (>30 species) was recorded at different sites throughout the GoM (Fig. 4a). The highest fish abundance was registered in the Yucatan continental slope, close to the Caribbean Sea (COERPES 2), with 412.46 individuals/ha recorded and a sample mean of 76.83 ± 19.18 individuals/ha (Fig. 4b). High fish diversity (Fig. 4c) and evenness (Fig. 4d) were recorded in several locations along the entire gulf, except in the area close to the Caribbean Sea (COBERPES 2).

Fifteen species extended their distribution into the continental slope of the southern GoM: *Eptatretus caribbeaus* Fernholm, 1982; *Ventrifossa mucocephalus* Marshall, 1973; *L. barbatulum*; *Brotulotaenia nigra* Parr, 1933; *Lophiodes beroe* Caruso, 1981;

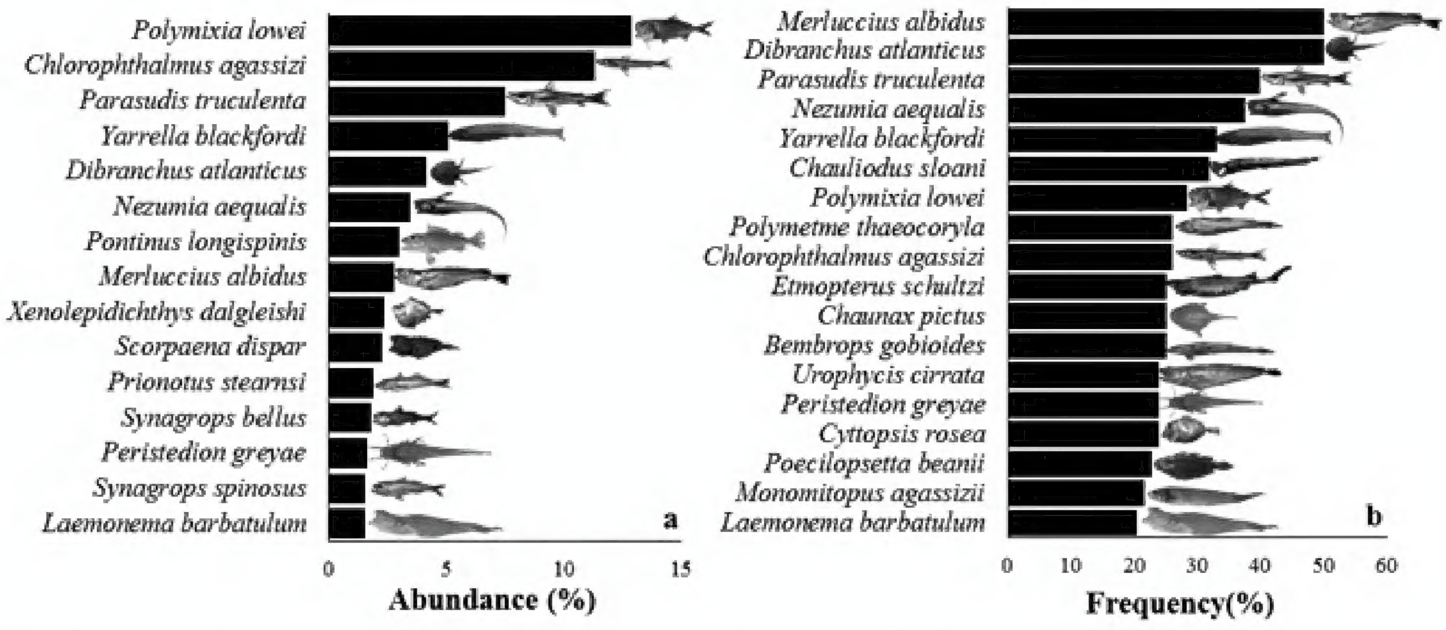

Figure 3. Abundance and frequency of the fish species: **a** Abundance (%) and **b** Frequency (%).

Table 2. List of the fish community. Presence and depth distribution ranges of fish species in the different cruises and literature reported (McEachran 2009, Ocean Biogeographic Information System (OBIS), Eschmeyer 2017, Moretzsohn et al. 2017, FishNet 2 2013, World Register of Marine Species 2017, and Froese and Pauly 2017). Key: * species which extended their distribution into the south of the Gulf of Mexico; ne: north-east; nw: north-west; se: south-east; sw: south-west; Al: Alabama; Atl: Atlantic; Bh: Bahamas; Bl: Belize; Cp: Campeche; Cb: Caribbean; Cu: Cuba; La: Louisiana; Ms: Mississippi; Mx: Mexico; QR: Quintana Roo; Tb: Tabasco; Tx: Texas; Tm: Tamaulipas; US: United States; Vz: Veracruz; Yc: Yucatan. ** Species which extended their depth ranges.

Specie	COBERPES cruises					Reported distribution and depth range (m)
	2	3	4	5	Species depth range (m)	
Antigonia capros Lowe, 1843		X			296	entire/50–900
Antigonia combatia Berry & Rathjen, 1959	X				308	Fl, Al, Bl/68–585
Aphanopus carbo Lowe, 1839			X		823	Atl, Vz/200–2300
Apristurus laurussonii (Saemundsson, 1922)	X				562–937	Ms, Al, Tx, Fl, Mx/500–1000
Argentina georgei Cohen & Atsaides, 1969**	X	X	X	X	300–825	entire/220–457
Argyropelecus aculeatus Valenciennes, 1850	X		X	X	436–825	entire/100–2056
Aristostomias tittmanni Welsh, 1923	X				974	entire/100–2000
Astronesthes similus Parr, 1927				X	611	entire/0–800
Atractodenchelys phrix Robins & Robins, 1970**	X			X	534–600	Cb, Fl, Cu, Vz/385–425
Baldwinella aureorubens (Longley, 1935)		X		X	300–611	Mx/91–610
Baldwinella vivanus (Jordan & Swain, 1885)	X		X	X	300	Mx/20–610
Barathronus bicolor Goode & Bean, 1886					846	entire/366–1561
Barbantus curvifrons (Roule & Angel, 1931)			X		953	ne, nw, Fl/0–4500
Bathyclupea argentea Goode & Bean, 1896**	X		X	X	300–677	entire/366–677
Bathycongrus dubius (Breder, 1927)				X	327	entire/120–886
Bathycongrus vicinalis (Garman, 1899)	X				477	Mx, US, Cb/101–503
Bathygadus favosus Goode & Bean, 1886	X	X			904–1068	entire/770–2745
Bathygadus macrops Goode & Bean, 1885**	X	X	X	X	494–1068	entire/200–777
Bathygadus melanobranchus Vaillant, 1888	X	X	X	X	602–1071	entire/400–2600
Bathypterois bigelowi Mead, 1958	X		X		534–780	entire/377–986
Bathypterois grallator (Goode & Bean, 1886)		X			953	entire/878–4720
Bathypterois quadrifilis Günther, 1878	X				865	entire/462–1408

Specie	COBERPES cruises 2	3	4	5	Species depth range (m)	Reported distribution and depth range (m)
Bathypterois viridensis (Roule, 1916)	X		X	X	593–904	entire/476–1477
Bathyuroconger vicinus (Vaillant, 1888)	X	X			477	ne, nw, Tm/100>1000
Bembrops anatirostris Ginsburg, 1955**	X	X	X	X	300–611	entire/82–538
Bembrops gobioides (Goode, 1880)**	X	X	X	X	300–825	entire/82–740
Benthodesmus simonyi (Steindachner, 1891)*	X			X	436–500	ne/200–900
Benthodesmus tenuis (Günther, 1877)	X	X	X	X	300–825	nw, ne, Mx/200–850
Bolinichthys supralateralis (Parr, 1928)	X		X	X	599–677	entire/40–850
Bregmaceros atlanticus Goode & Bean, 1886				X	300–462	entire/50–2000
Bregmaceros cantori Milliken & Houde, 1984***	X				812	ne/0–475
Bregmaceros houdei Saksena & Richards, 1986***	X		X		346–611	ne/>50
Brotulotaenia nigra Parr, 1933***			X	X	800–953	Atl/1000–1100
Caulolatilus cyanops Poey, 1866		X			300–500	entire/45–459
Chascanopsetta lugubris Alcock, 1894	X				358–426	entire/60–3210
Chauliodus sloani Bloch & Schneider, 1801	X	X	X	X	300–953	entire/0–4700
Chaunax pictus Lowe, 1846	X	X	X	X	321–865	ne, nw, Tb/200–978
Chiasmodon sp.				X	780	ne, Tb, QR
Chlorophthalmus agassizi Bonaparte, 1840	X	X	X	X	300–825	entire/50–3000
Citharichthys dinoceros Goode & Bean, 1886	X				336–423	ne, QR, Bl, Cu/180–2000
Coccorella atlantica (Parr, 1928)			X		995	entire/50–1000
Coelorinchus caribbaeus (Goode & Bean, 1885)**		X	X	X	300–825	entire/200–700
Coelorinchus caelorhincus (Risso, 1810)	X		X	X	436–800	entire/90–1485
Coelorinchus occa (Goode & Bean, 1885)	X	X		X	321–820	entire/400–2220
Coelorinchus ventrilux Marshall & Iwamoto, 1973	X	X	X	X	300–534	se, sw/300>500
Coloconger meadi Kanazawa, 1957		X	X		494–846	Tm, Vz, ne, nw/366–925
Conocara macropterum (Vaillant, 1888)**	X	X		X	354–1071	Mx/800–2200
Coryphaenoides alateralis Marsahll & Iwamoto, 1973	X				904	Mx/1035–1116
Coryphaenoides mexicanus (Parr, 1946)	X				534–937	Mx/110–1600
Coryphaenoides zaniophorus (Vaillant, 1888)	X		X	X	677–1065	entire/400–2775
Cruriraja rugosa Bigelow & Schroeder, 1958	X	X	X		321–825	Mx/366–1007
Cyttopsis rosea (Lowe, 1843)	X	X	X	X	300–825	Mx/100>1000
Dactylobatus clarkii (Bigelow & Schroeder, 1958)	X				626	Mx/366–1000
Diaphus dumerilii (Bleeker, 1856)	X		X		423–823	entire/0–850
Diaphus fragilis (Tåning, 1928)			X		823	entire/15–1313
Dibranchus atlanticus Peters, 1876	X	X	X	X	300–1071	entire/22–1300
Dicrolene introniger Goode & Bean, 1883		X	X	X	321–1071	entire/200–1785
Diplacanthopoma brachysoma Günther, 1887	X		X		494–766	entire/439–1670
Dipturus oregoni (Bigelow & Schroeder, 1958)		X			611	Mx/369–1079
Dipturus teevani (Bigelow & Schroeder, 1951)				X	540–800	Cp/311–940
Diretmoides pauciradiatus (Woods, 1973)**	X	X	X	X	321–800	entire/0–600
Epigonus denticulatus Dieuzeide, 1950	X	X		X	354–800	Mx/130–830
Epigonus macrops (Brauer, 1906)			X		766–823	entire/550–1300
Epigonus occidentalis Goode & Bean, 1896	X			X	573–700	Vz, Tm/360–737
Epigonus oligolepis Mayer, 1974	X				540–619	Mx/380–660
Epigonus pandionis (Goode & Bean, 1881)		X	X	X	419–494	Cp/200–600
Epigonus pectinifer Mayer, 1974			X		346–677	Mx/100–1200
Eptatretus caribbeaus Fernholm, 1982***	X				597	Cb/300–400
Espringeria folirostris Bigelow & Schroeder, 1951		X	X	X	354–800	ne, nw, se, sw/50–1052
Etmopterus schultzi Bigelow, Schroeder & Springer, 1953	X	X	X	X	300–852	entire/200–1000
Etmopterus virens Bigelow, Schroeder & Springer, 1953	X	X	X	X	392–800	Mx/100–1000
Gadella imberbis (Vaillant, 1888)	X	X	X	X	300–974	Mx, Cb, Cu/70>900
Gadomus arcuatus (Goode & Bean, 1886)**	X	X	X	X	321–1068	entire/610–1370
Gadomus dispar (Vaillant, 1888)		X	X		611–677	Tm/548–1105
Gadomus longifilis (Goode & Bean, 1885)**	X	X	X	X	321–1071	entire/630–2168

Specie	COBERPES cruises 2	3	4	5	Species depth range (m)	Reported distribution and depth range (m)
Galeus arae (Nichols, 1927)	X	X			358–780	Mx/250–750
Gibberichthys pumilus Parr, 1933	X				746	entire/300–1100
Gigantura chuni Brauer, 1901	X				540	entire/0–1830
Gymothorax kolpos Böhlke & Böhlke, 1980	X				336	entire/30–300
Halieutichthys aculeatus (Mitchill, 1818)		X			611	entire/8–820
Halosaurus ovenii Johnson, 1864	X	X	X	X	321–1068	entire/300>2000
Helicolenus dactylopterus (Delaroche, 1809)	X				426	Mx/50–1100
Hemantias leptus (Ginsburg, 1952)		X			611	entire/35–640
Heptranchias perlo (Bonnaterre, 1788)				X	436	entire/0–1000
Hollardia hollardi Poey, 1861	X	X		X	300–800	Mx/230–915
Hoplostethus mediterraneus Cuvier, 1829*	X		X	X	354–800	ne/100–1750
Hoplunnis tenuis Ginsburg, 1951**		X		X	302–611	entire/30>400
Hydrolagus alberti Bigelow & Schroeder, 1951		X	X	X	494–1068	entire/348–1470
Hydrolagus mirabilis (Collett, 1904)	X		X	X	462–812	entire/450–1933
Hygophum reinhardtii (Lütken, 1892)	X				611	entire/0–1100
Hymenocephalus aterrimus Gilbert, 1905		X			354–540	entire/340–1348
Hymenocephalus billsam Marshall & Iwamoto, 1973	X				573–711	entire/400–900
Hymenocephalus italicus Giglioli, 1884	X	X	X	X	428–800	entire/100–1400
Ijimaia antillarum Howell Rivero, 1935**	X	X	X	X	462–1068	entrire/439>700
Laemonema barbatulum Goode & Bean, 1883*	X	X	X	X	426–937	QR/50–1620
Leptoderma macrops Vaillant, 1886	X	X	X	X	700–1065	Mx/500–2000
Leucoraja garmani (Whitley, 1939)**	X	X	X	X	300–800	Mx/37–530
Leucoraja lentiginosa (Bigelow & Schroeder, 1951)**	X	X	X	X	346–852	entire/53–538
Lophiodes beroe Caruso, 1981*	X	X		X	462–735	ne/347–860
Lophiodes monodi (Le Danois , 1971)**	X	X		X	419–800	ne, se/366–549
Lophiodes reticulatus Caruso & Suttkus, 1979	X				590–619	entire/64–820
Lophius gastrophysus Miranda Ribeiro, 1915	X				599	entire/40–700
Luciobrotula corethromycter Cohen, 1964	X	X			606–846	Mx/220–1830
Macroramphosus scolopax (Linnaeus, 1758)*	X				308	ne, nw, Cu/25–600
Malacocephalus laevis (Lowe, 1843)	X	X	X	X	300–800	entire/200–1000
Malacocephalus occidentalis Goode & Bean, 1885	X	X	X	X	308–800	entire/140–1495
Merluccius albidus (Mitchill, 1818)	X	X	X	X	300–852	entire/80–1170
Monolene sessilicauda Goode, 1880	X	X			336–1046	ne, nw, sw/0>3000
Monomitopus agassizii (Goode & Bean, 1896)	X	X	X	X	300–1071	entire/48–1125
Myctophum nitidulum Garman, 1899			X		823	entire/0–1537
Nemichthys scolopaceus Richardson, 1848		X			321	ne, nw, Yc, Cu/100–4337
Neoepinnula americana (Grey, 1953)			X	X	300–370	Yc/0–600
Neoscopelus macrolepidotus Johnson, 1863*	X	X	X	X	300–852	ne, nw, Cu, Tb/300–1180
Neoscopelus microchir Matsubara, 1943*	X			X	300–814	ne, nw, Cu, Bh/60>900
Nettastoma melanurum Rafinesque, 1810	X	X	X	X	300–852	entire/37–1647
Nezumia aequalis (Günther, 1878)	X	X	X	X	321–973	entire/200–2320
Nezumia cyrano Marshall & Iwamoto, 1973**	X	X	X	X	321–1071	entire/400–1324
Nezumia suilla Marsahll & Iwamoto, 1973	X				904–1046	entire/860–1500
Oxinotus caribbaeus Cervigón, 1961**				X	800	Yc/402–457
Parasudis truculenta (Goode & Bean, 1896)	X	X	X	X	300–846	entire/0>1000
Parazen pacificus Kamohara, 1935	X				300	Cp, Cu/145–512
Peristedion ecuadorense Teague, 1961*	X	X			392–814	ne, nw/324–910
Peristedion greyae Miller, 1967**	X	X	X	X	300–1071	entire/60–914
Peristedion longispatha Goode & Bean, 1886	X			X	302–553	entire/101–787
Peristedion miniatum Goode, 1880		X	X	X	300–500	entire/64–910
Peristedion thompsoni Fowler, 1952*	X				358–423	ne, nw, Cu/115–475

Specie	COBERPES cruises					Reported distribution and depth range (m)
	2	3	4	5	Species depth range (m)	
Peristedion truncatum (Günther, 1880)	X	X	X		336–852	Vz, Yc/155–910
Photostomias guernei Collett, 1889	X				540–772	entire/500–3100
Poecilopsetta beanii (Goode, 1881)	X	X	X	X	300–825	entire/155–1636
Polyipnus asteroides Schultz, 1938*	X			X	300–820	ne, nw/0>1000
Polymetme thaeocoryla Parin & Borodulina, 1990	X	X	X	X	300–953	entire/165–1400
Polymixia lowei Günther, 1859	X	X	X	X	300–825	entire/0>2000
Pontinus longispinis Goode & Bean, 1896**	X	X		X	300–611	entire/50–440
Prionotus alatus Goode & Bean, 1883**		X			611	Yc/35–457
Prionotus stearnsi Jordan & Swain, 1885	X	X	X		308–346	entire/11–549
Pristipomoides macrophthalmus (Müller & Jelks, 1848)**		X			611	ne, nw, Cp/110–550
Promethichthys prometheus (Cuvier, 1832)	X			X	540–609	ne, Cu, Yc/80–800
Pseudomyrophis frio (Jordan & Davis, 1891)**		X			494	sw, Atl, Yc/0–180
Pseudoraja fischeri Bigelow & Schroeder, 1954	X				534–580	Yc/412–576
Rinoctes nasutus (Koefoed, 1927)		X			1068	ne, nw, Yc/1000–4337
Rouleinia maderensis Maul, 1948	X	X	X		852–1068	ne, Cu/595–1450
Saurida caribbaea Breder, 1927	X		X		308–422	entire/4–460
Saurida normani Longley, 1935	X	X		X	300–611	entire/25–550
Scopelosaurus smithii Bean, 1925			X		953	ne, Vz/50>3000
Scorpaena dispar Longley & Hildebrand, 1940**	X	X	X	X	300–812	entire/0>500
Scyliorhinus retifer (Garman, 1881)	X			X	300–812	entire/36–750
Setarches guentheri Johnson, 1862	X				392	ne, nw, Yc, QR/150–780
Sigmops elongatum (Günther, 1878)	X	X	X	X	494–1068	entire/25–1463
Sphagemacrurus grenadae (Parr, 1946)**	X	X	X	X	820–1071	entire/1000–1960
Squalogadus modificatus Gilbert & Hubbs, 1916	X		X		865–995	entire/50–1740
Squalus cubensis Howell Rivero, 1936**	X	X	X	X	300–608	entire/60>500
Squatina dumeril Lesueur, 1818			X		354–370	entire/0–1375
Steindachneria argentea Goode & Bean, 1886			X	X	300–370	entire/350–550
Stephanoberyx monae Gill, 1883	X	X	X		628–953	entire/945–4777
Sternoptyx diaphana Hermann, 1781	X	X	X		577–1065	entire/300–3676
Sternoptyx pseudobscura Baird, 1971	X		X		628–953	entire/0>3000
Stomias affinis Günther, 1887	X	X			611–772	entire/0–3180
Symbolophorus rufinus (Tåning, 1928)				X	327	entire/0–3000
Synagrops bellus (Goode & Bean, 1896)	X	X	X	X	300–974	entire/00>900
Synagrops spinosus Schultz, 1940**	X	X	X	X	300–825	entire/0–544
Synaphobranchus affinis Günther, 1877					820	entire/290–2400
Synaphobranchus oregoni Castle, 1960	X	X	X	X	377–1071	entire/45–1900
Synchiropus agassizii (Goode & Bean, 1888)	X	X			336–426	Mx, Cb, Cp/0–500
Tetronarce nobiliana (Bonaparte, 1835)				X	540	ne, nw, Cp, Yc/0–530
Thaumatichthys binghami Parr, 1927**	X				820	ne, nw, Cb/1100–4032
Trachonurus sulcatus (Goode & Bean, 1885)**	X	X	X	X	626–1068	entire/700–1500
Trachyscorpia cristulata (Goode & Bean, 1896)					619–628	ne, Cb, Mx/130–1100
Urophycis cirrata (Goode & Bean, 1896)**		X	X	X	300–825	entire/27>700
Venefica procera (Goode & Bean, 1883)	X		X	X	327–953	ne, nw, Tm, Vz/326–2340
Ventrifossa macropogon Marshall, 1973**	X	X	X		300–846	Tm, Yc/439–1000
Ventrifossa mucocephalus Marshall, 1973***	X	X	X	X	300–814	ne, Cb/450–732
Xenocephalus egregius (Jordan & Thompson, 1905)	X		X		370–423	entire/180–440
Xenodermichthys copei (Gill, 1884)	X			X	590–865	ne, nw, Vz, Tb/100–2650
Xenolepidichthys dalgleishi Gilchrist, 1922	X		X		346–547	Tm, Cp/90–900
Yarrella blackfordi Goode & Bean, 1896	X	X	X	X	321–1071	entire/350–1000
Zalieutes mcgintyi (Fowler, 1952)	X				300–394	entire/70–500
Zenion hololepis (Goode & Bean, 1896)**	X	X	X	X	300–825	Cp, Tb/180–700

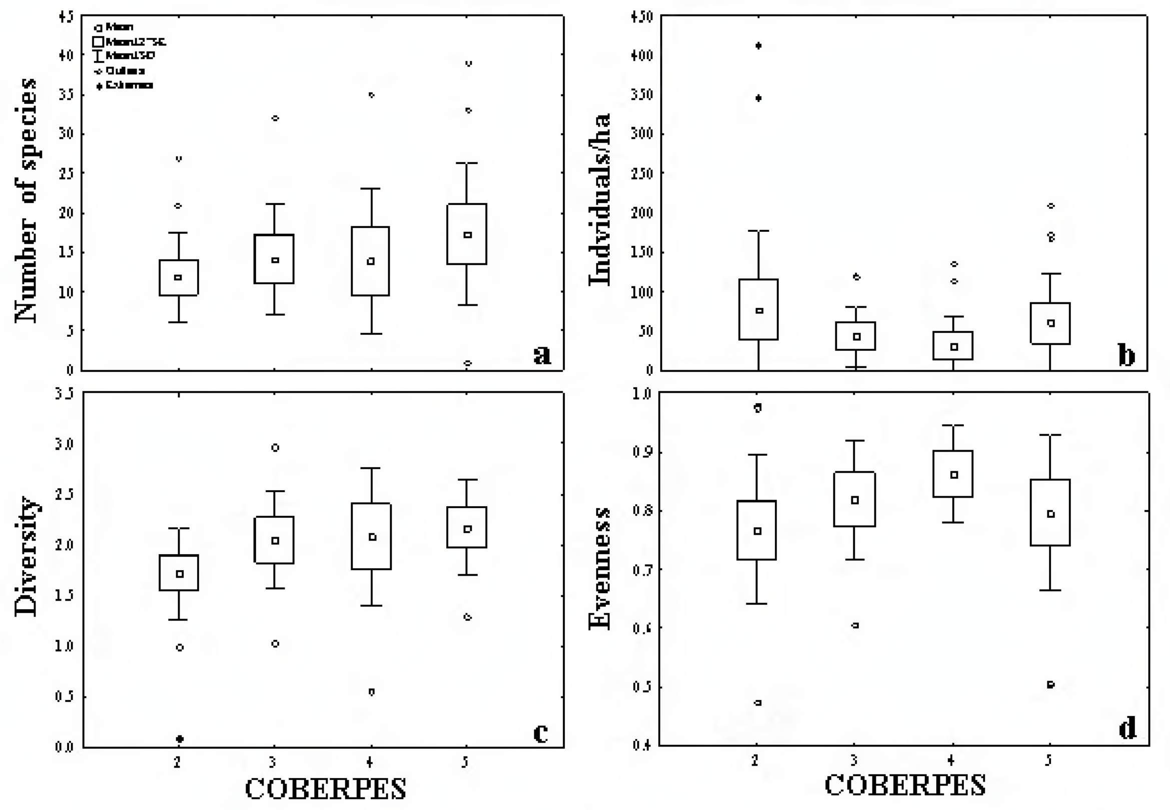

Figure 4. Community parameters for each cruise (COBERPES): **a** Species richness (number of species); **b** Abundance (individuals/ha); **c** Diversity (Shannon-Wiener); **d** Evenness (Pielou).

Hoplostethus mediterraneus Cuvier, 1829; *Benthodesmus simonyi* (Steindachner, 1891); *Macroramphosus scolopax* (Linnaeus, 1758); *Bregmaceros cantori* Milliken & Houde, 1984; *Bregmaceros houdei* Saksena & Richards, 1986; *Peristedion ecuadorense* Teague, 196; *Peristedion thompsoni* Fowler, 1952; *Polyipnus asteroides* Schultz, 1938; *Neoscopelus microchir* Johnson, 1863, and *Neoscopelus macrolepidotus* Matsubara, 1943 (Table 2).

Thirty seven species increased its depth range distribution (Table 2). Three of the most abundant species recorded an average depth lower than 400 m (Fig. 3): *Prionotus stearnsi* Jordan & Swain, 1885 (318 ± 24.57 m); *Xenolepidichthys dalgleishi* Gilchrist, 1922 (379 ± 33.05 m) and *Pontinus longispinis* Goode & Bean, 1896 (376 ± 114.03 m). Many of the species showed a wide depth range distribution (400>800); however, only two of them presented the highest average depth: *Monomitopus agassizii* (Goode & Bean, 1896) and *Y. blackfordi* (743 ± 223.92 m and 749 ± 172.95 m, respectively) (Fig. 5).

Discussion

The species accumulation curve suggests that we registered most of the fish species found on soft bottoms of the continental slope of the southern GoM. Nevertheless, since the species accumulation curve continued to increase, the inventory still appears to be inconclusive. This situation is congruent with the fact that the sampling effort in the GoM deep waters has been low, particularly in the south. We identified 177 species which represent 12% of the total fish species (1541) reported for all habitats in continental shelf and deep waters including demersal and pelagic fishes of the GoM

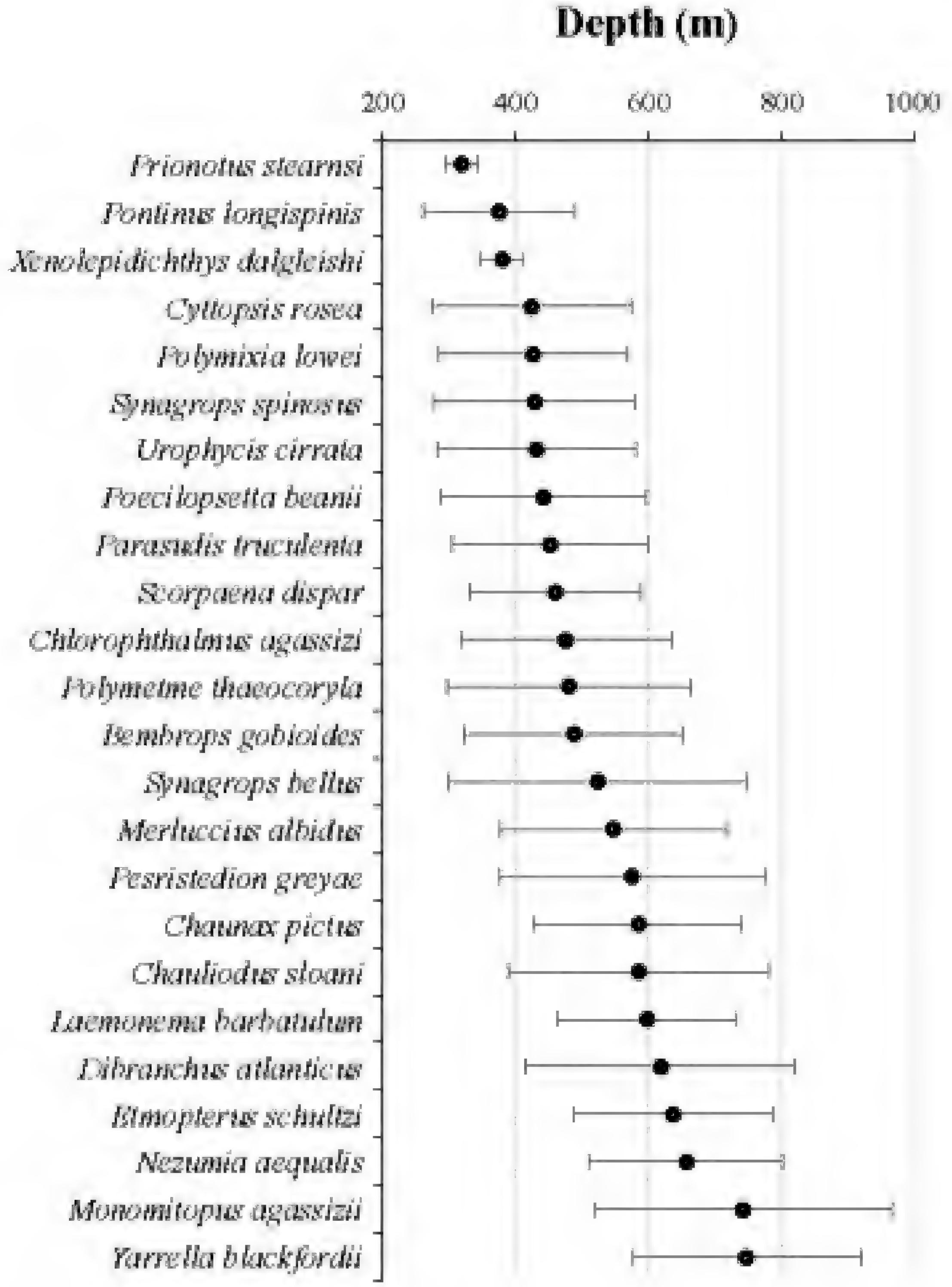

Figure 5. Depth of occurrence of the most abundant fish species: average depth ± standard deviation (SD).

(McEachran 2009). The only previous systematic study using a similar sampling gear was conducted in the northern GoM by Powell et al. (2003) who recorded 93 demersal fish species for the upper (315–785 m) and mid slope (686–1369 m).

Based on the fish list elaborated by McEachran (2009) we counted 335 benthic and demersal fishes for the continental slope of the GoM. This number is 30 % higher than the 235 summed from this paper and Powell et al. (2003) study. It must be noted that McEachran list includes fishes collected with other gears and also in other habitats, like hard bottoms. Nonetheless, three fish species can be added to McEachran list: *Kali indica* Lloyd, 1909, following Powell et al. (2003) and two species found in this research *E. caribbeaus* and *B. nigra*. In this way, a total compilation of 338 species of benthic and demersal

fishes can be listed for this ecosystem. Additionally, 15 species extended their distribution into the south of the GoM (Table 2). It must also be noted that 37 species extended their depth ranges, nine of them were recorded in deeper ranges and 28 species in shallower depths than previously reported in literature. Most of the species showed a wide distribution depth range which is consistent with the distribution pattern of deep water fishes.

The highest species richness recorded in the continental slope of the Campeche Bay (COBERPES 5), is probably influenced by the high freshwater discharge of the largest hydrological system in the southern GoM: Grijalva-Usumacinta during summer, which inputs 62% of the total freshwater to the mexican GoM (Day et al. 2004), similar to what Powell et al. (2003) found in the northern GoM, near the mouth of the Mississippi River. Likewise, the upwelling produced by cyclonic gyres in the Campeche Bank (De la Lanza-Espino and Gómez-Rojas 2004, Durán-Campos et al. 2017), could be playing an important ecological role. These factors together incorporate large concentrations of nutrients which may trigger local productivity, and subsequently the diversity of demersal fishes on the continental slope in this region. Fish richness and diversity difference between COBERPES 3 and COBERPES 5 could also be influenced by seasonal productivity variations due to current pattern change in the area.

Five species captured in this survey are of commercial importance in other parts of the world. *M. albidus* was one of the second most frequent species (50%) which accounted greatly to total biomass (72.296 kg) and presented relatively large sizes (total length = 103–555 mm). This species could have a fishing potential in the GoM, as it was an important fishing resource in the US Atlantic in the early 1990s, but its production decreased significantly over a 10-year period of exploitation (Traver et al. 2012). Other taxa of commercial interest in the Atlantic such as *H. mirabilis*, *H. dactylopterus* and particularly *A. carbo* (one individual), are important fishing resources in the central and northern regions of the eastern Atlantic Ocean (Bensch et al. 2009, Pajuelo et al. 2010). Another species registered in the present study was *L. gastrophysus*, which was a significant deep water fishing resource in Brazil from 2000 to 2007 (Álvarez et al. 2009). However, the fishing potential of these species in the GoM is still to be defined with further studies.

Compiling data of fish species of this study as well as from the literature (McEachran and Fechhelm 1998, Powell et al. 2003 and McEachran 2009), we found that the north and south parts of the GoM share 97% of the species recorded on soft bottoms of the continental slope of the whole gulf. On the other hand, more than 63% of the species (n = 44) recorded for the Caribbean Sea (n = 69) (Anderson et al. 1985, Saavedra-Díaz et al. 2004, Paramo et al. 2015) also occur in the GoM. McEachran (2009) pointed out that this fish similarity is influenced by fauna from the central Atlantic (the region between North Carolina and the Great and Lesser Antilles, including The Bahamas, Bermuda islands, and South America) due to the Loop Current effect that connects the Yucatan and Florida currents (Monreal-Gómez et al. 2004, NOAA 2016).

This result is consistent with the distribution of deep water fishes inhabiting large bathymetric areas due to more stable environmental conditions in these habitats (Clark et al. 2010). A similar distribution pattern has been recorded in several studies done in the world, for example in the Mediterranean Sea (Moranta et al.1998), in the Atlantic (Menezes et al. 2006, 2015; Magnussen 2002; Bergstad et al. 2012; Koslow 1993;

Quattrini et al. 2015); in the Caribbean (Quattrini et al. 2017), and in the northern of the GoM (Powell et al. 2003).

Our results suggest that a high number of species dwelling on the continental slope are shared between the north and south of the GoM. We recorded an extension in distribution into the south of the GoM and also bathymetrically of several fish species. New records are highly likely to be increased if sampling effort continues both geographically and bathymetrically, since the species cumulative curve did not reach an asymptote. This research contributes to the knowledge of the deep water fish community of the GoM, never studied before in the southern region. However, information needs to be enhanced since deep water natural resources of the southern GoM could be subject to increasing human pressures in the near future.

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